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TITLE: Rotary positive-displacement fluid-machines

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ABSTRACT:

A sliding-vane compressor for e.g. a refrigerant, has discharge ports 12 controlled by spring-biassed non- return valves 14, which may be of the reed type (as shown). The areas of the ports may diminish progressively (as shown) so that the pressures at which the valves open increase correspondingly. Each of the vanes 10 on the rotor 9 may have a radially outer portion made of a wear-resistant material, Fig. 4 (not shown), examples of this material being given in the specification. The machine may be employed as a motor instead of a compressor, Fig. 3 (not shown). <IMAGE>

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(54) **Rotary positive-displacement fluid-machines**

(57) A sliding-vane compressor for e.g. a refrigerant, has discharge ports 12 controlled by spring-biassed non-return valves 14, which may be of the reed type (as shown). The areas of the ports may diminish progressively (as shown) so that the pressures at which the valves open increase correspondingly. Each of the vanes 10 on the rotor 9 may have a radially outer portion made of a wear-resistant material, Fig. 4 (not shown), examples of this material being given in the specification. The machine may be employed as a motor instead of a compressor, Fig. 3 (not shown).

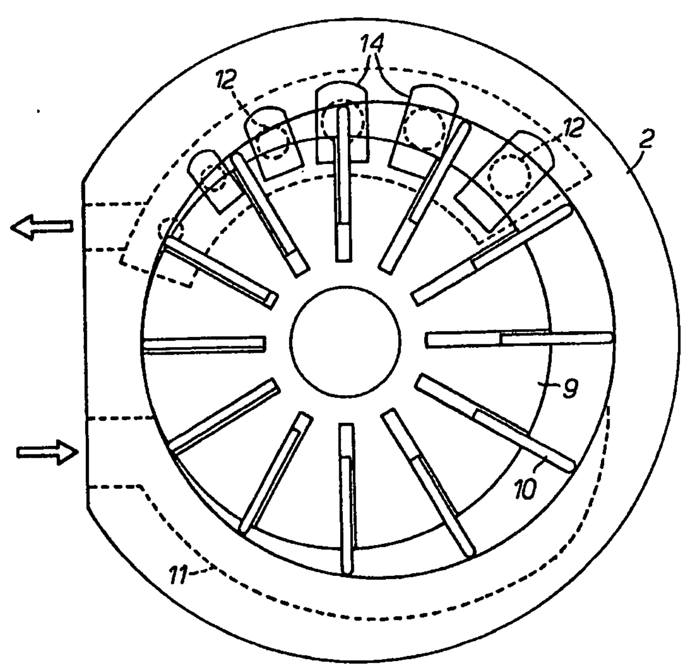

FIG. 1.

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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

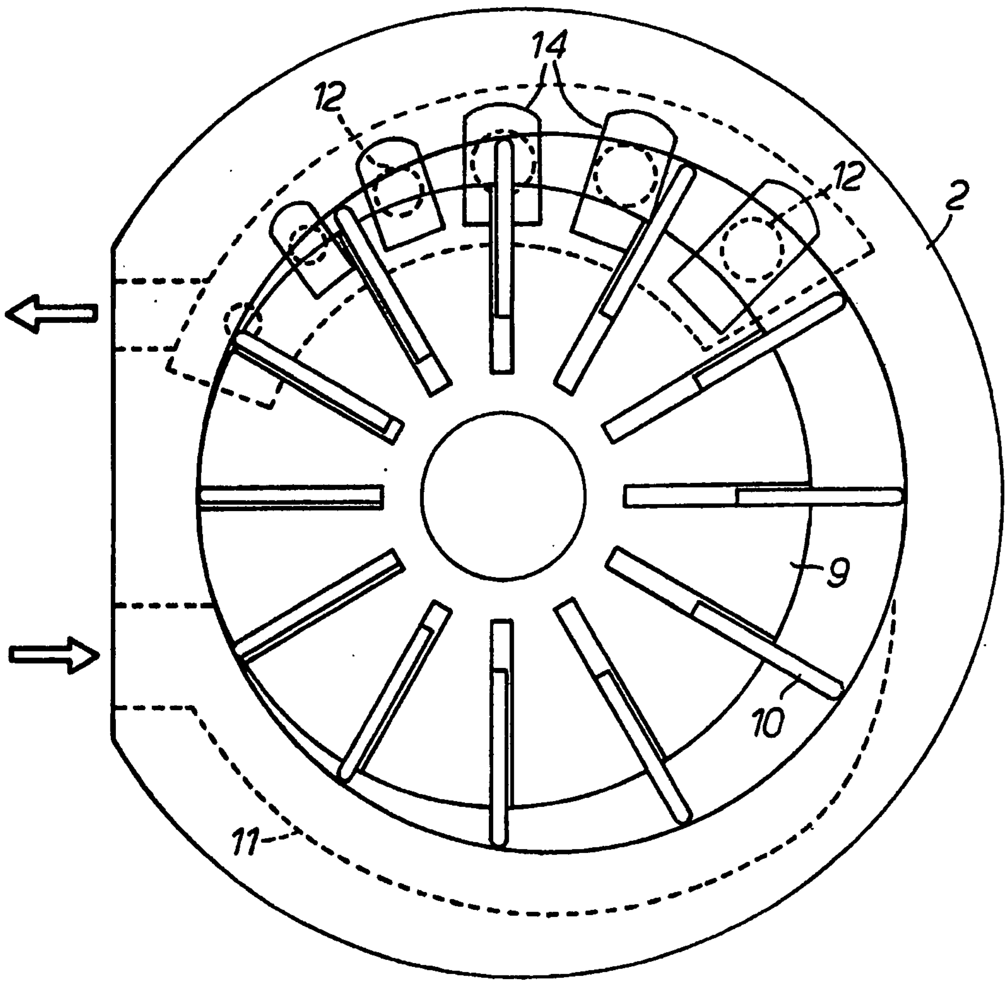


FIG. 1.

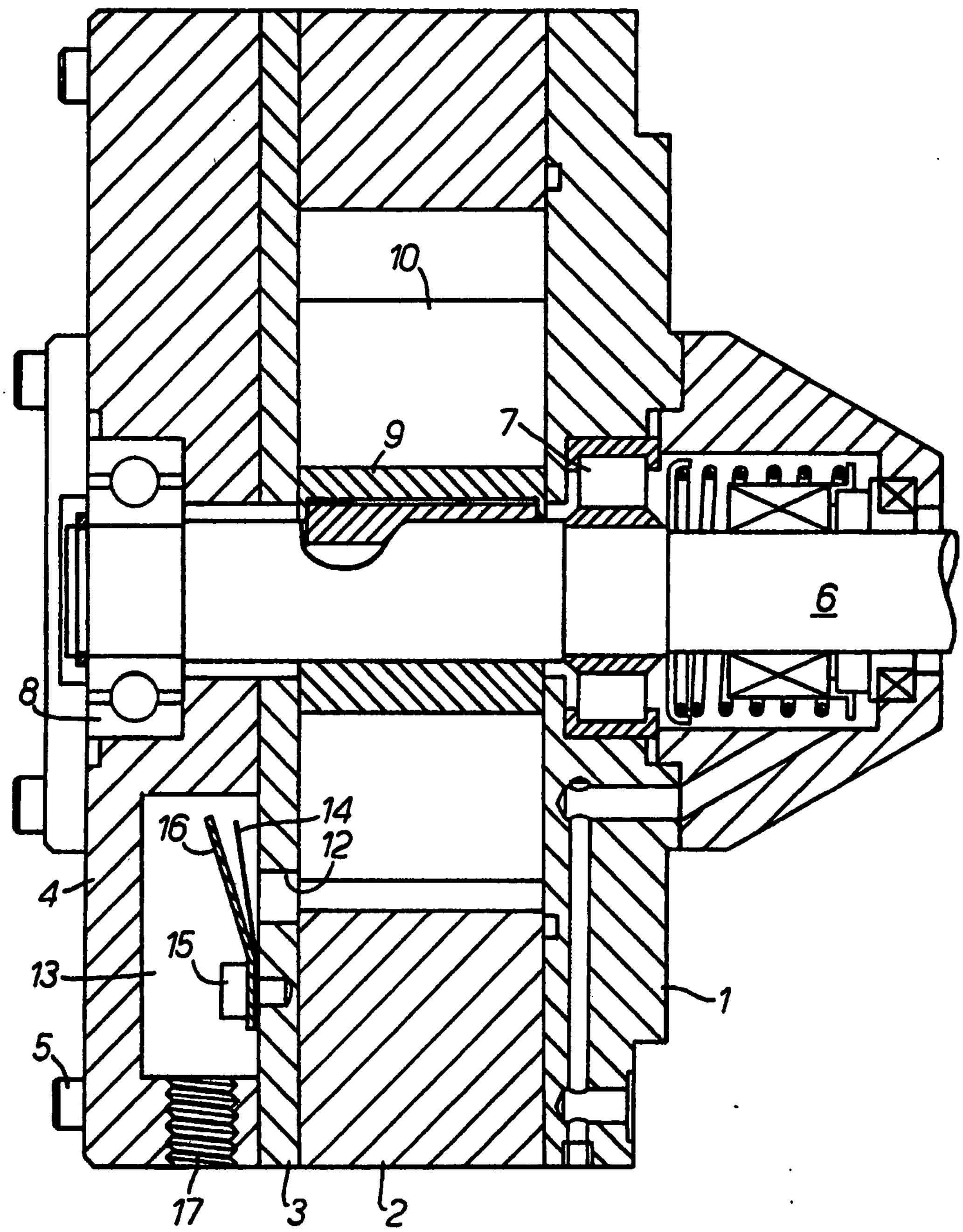


FIG.2.

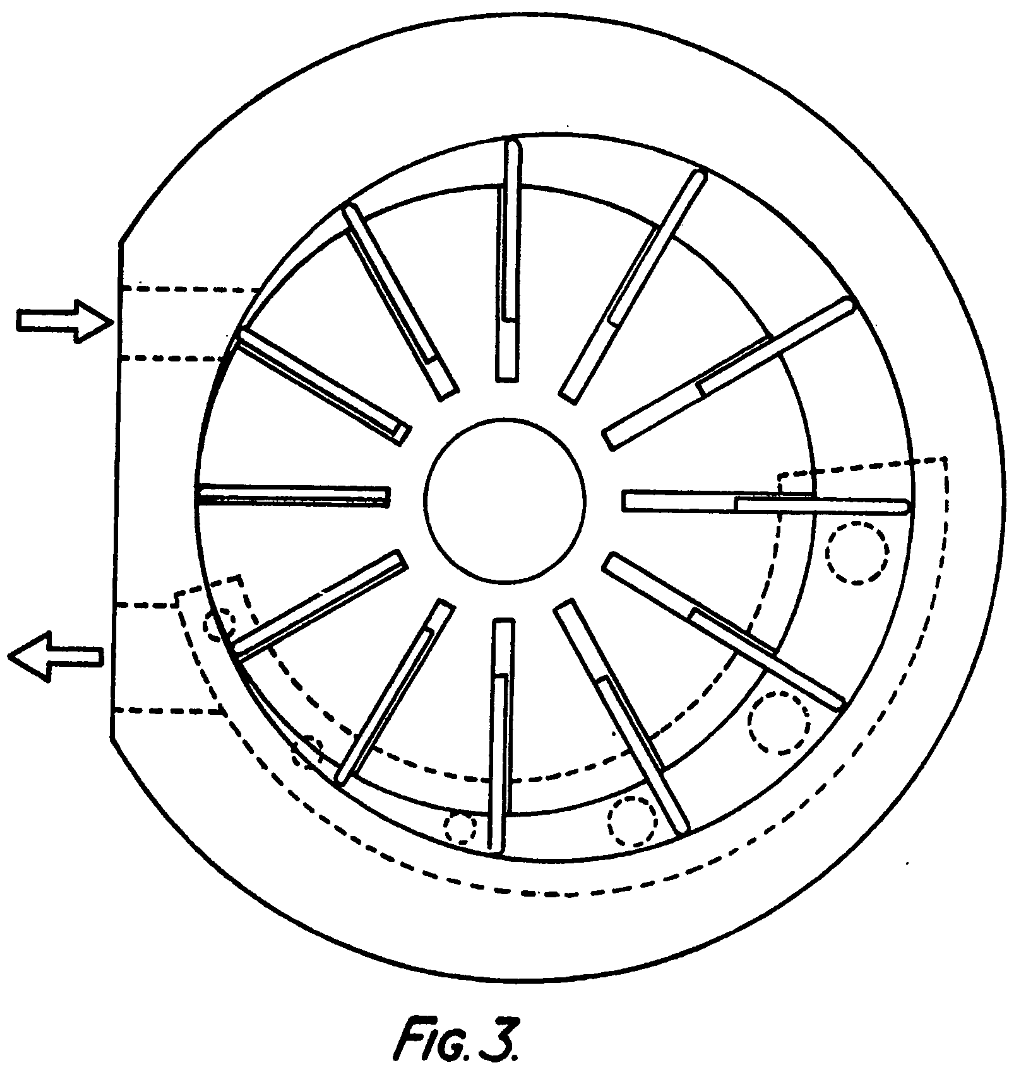
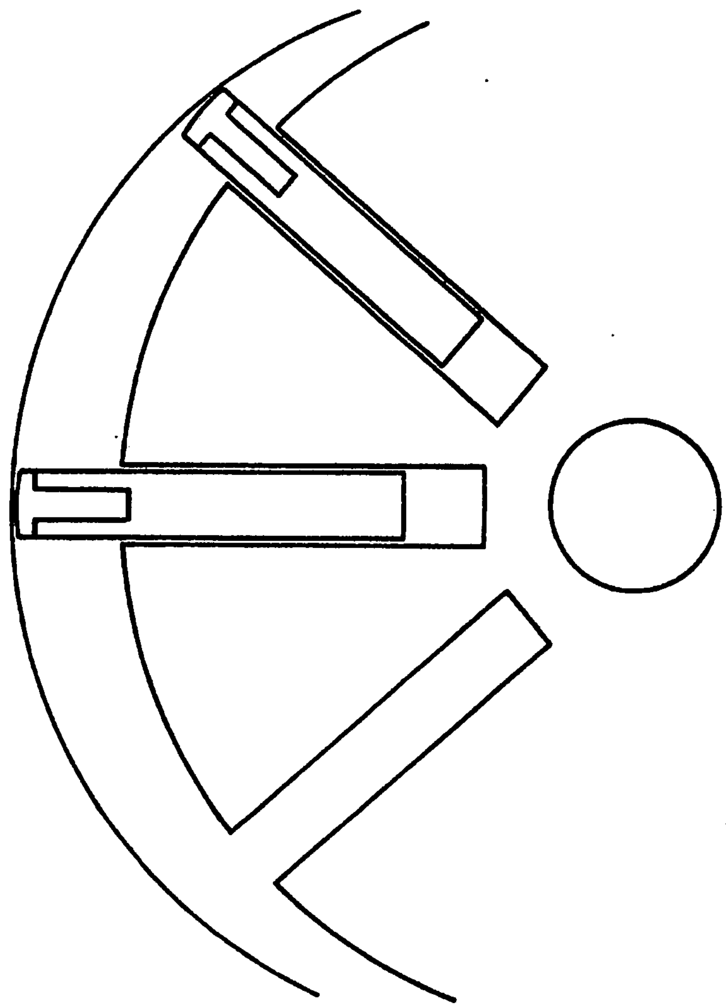


FIG. 3.



(A)
MOULDED INSERT

(B)
PLAIN INSERT

FIG. 4.

SPECIFICATION

Improvements relating to rotary vane compressors and motors

This invention relates to rotary vane compressors and motors. It is convenient to explain it largely in terms of a compressor for a refrigeration system, but it will be understood that it has many other applications.

In a vaporisation-condensation closed gas thermodynamic cycle as used for refrigeration and heat pumps, the ratio of compression varies with the changes which occur in evaporating and condensing temperatures. In a typical system, variations in compression ratio between 2.5:1 to 4.5:1 are common, while in refrigeration systems compression ratios as low as 1.5:1 and as high as 12:1 are often required. For this reason a refrigeration compressor working on a fixed compression ratio offers a serious disadvantage because, except by occasional chance, the machine is either over-compressing the gas or under-compressing, both conditions causing serious loss of efficiency measured in terms of work done/power input.

A valve in the compressor discharge port capable of following, that is opening and closing as each cell (or compartment between adjacent vanes) discharges its gas, would solve the problem. However, the multicell high speed compressor necessary in refrigerator systems renders this solution impossible because a valve of adequate strength and operating life to follow the discharge gas pulse rate is impractical. For instance, an 8-cell rotary compressor running at 3000 RPM would require the valve to open and close 24,000 times a minute. To achieve this the inertial mass of the valve would have to be so small that it would break if subjected to the slightest hydraulic shock. This is impossible to avoid in a refrigeration plant because oil is in continuous circulation and droplets and sometimes slugs of refrigerant liquid enter the compressor.

The problem to be solved is how to provide self regulation of the compression ratio in relation to instantaneous inlet and outlet pressure conditions without back flow of gas on the one hand and over compression on the other.

It is a further requirement of a multi-cell rotary vane compressor that protection is provided against mechanical damage arising from hydraulic lock. Hydraulic lock arises as a result of liquid migration into the inlet side of the compressor during standstill. The liquid is virtually incompressible, and on start-up a wedge of liquid is entrained and will either break one of the vanes as the cell volume decreases during its rotation or, if the blades have adequate strength, the compressor will stall. In practice the normal occurrence is for the blades to break as latest practice is to use lightweight, low friction composition plastics and carbon materials which do not have high mechanical strength.

It is believed that the invention described satisfies both requirements, that is providing a variable compression ratio and mechanical protection against hydraulic lock.

According to the present invention, there is provided a rotary vane compressor having a plurality of outlets, circumferentially spaced, each outlet having a spring biased closure means which opens when there is a predetermined pressure differential between the compressor cell with which the closure means is momentarily associated and an outlet manifold with which all the outlets are associated.

The compressor cells are continuously changing in shape, volume and position as the rotor spins to draw in and then compress the gas. As they reach the compression zone, they sweep over the outlets, cooperating with varying subgroups of them. If the cell pressure is high in relation to the downstream outlet pressure, then the closure means will open, while if the reverse obtains, the closure means will stay closed until the manifold pressure drops. The closure means are conveniently leaf springs over apertures in an end plate defining a wall of the rotor chamber.

For a better understanding of the invention, one embodiment will now be described, by way of example, with reference to the accompanying drawings, in which:—

Figure 1 is a radial section of a rotary vane compressor,

Figure 2 is an axial section of the compressor of Figure 1, and

Figure 3 is a radial section of a rotary vane expansion motor.

The compressor has a hollow cylindrical body made up from a base plate 1, a ring 2 (not necessarily circular), a valve plate 3 and a thick end plate 4, these being secured together by bolts 5. A rotor shaft 6 is mounted in bearings 7 and 8 in the plates 1 and 4 respectively, this shaft being eccentric with respect to the chamber through which it extends. It carries a cylindrical block 9 with equally spaced radial slots housing vanes 10. These are urged by centrifugal force against the inside of the ring 2 and, with the block 9, slide over the inner faces of the plates 1 and 3. This is conventional vane compressor construction, and there will be an inlet 11, shown partly by broken lines in Figure 1, to the cells between adjacent vanes which are expanding in volume.

Instead of a fixed and continuously open outlet port, there is an array of small ports 12 in the valve plate 3, circumferentially spaced, over an arc of more than 90° in this example, and all registering with the cells that are reducing in volume. This arc may be of greater or lesser extent, and there may be more of fewer than the six ports shown. They progressively decrease in size towards the high pressure end, and each one opens into an outlet manifold 13 in the plate 4 via a non-return valve 14. These valves are each in the form of a leaf spring or reed fixed at one end to the plate by a screw 15, which also secures a rigid angled backing plate 16 to limit the opening of the valve. In the relaxed state, the spring is such that

the associated port 12 is closed. The outlet 17 from the manifold 13 will lead to the condenser or high pressure side of the system.

Although in the arrangement described the discharge ports are formed in the plate 3, the ports could be located in the ring 2.

In operation, gas is drawn through the inlet 11 and is compressed by rotation of its cell until it reaches a pressure just slightly above the pressure in the manifold 13. Gas escapes from the compression cell through the appropriate non-return valve 14 until the pressure differential between the cell and the gas chamber 3 is equalised. As the cell rotates further and the volume is reduced, more gas escapes through the next valve and so on until all the gas is discharged from the cell. At a very low compression ratio, that is, when the ratio of pressure between the evaporator and the condenser is small, gas will escape through all the non-return valves from the compression cells to the manifold 13. Conversely, at the very highest compression ratio, maybe only the last port 12 will become effective. In a typical operating cycle, where cyclic variations in condensing and evaporating conditions occur, the number of communicating ports which will be effective will vary according to the compression ratio.

Because of the continuous pressure ripple at any point in the compression arc, the non-return valves will tend to oscillate in sympathy. Generally however, the frequency of the transient pressure pulses will be too high for the valve to follow and the net effect is for the valve to be open or closed according to whether the average pressure in the cell during its passage past any particular port is greater or less than the pressure in the manifold 13.

With the arrangement described, if the number of communicating valve ports is adequate, there will not be any over-compression or under-compression of the cell in relation to the pressure in the outlet manifold. In practice, the discharge port spacing has to be related to the rotor vane spacing. That is to say if the vanes are spaced at 45° the discharge ports must also be spaced at not more than 45° so that there is always at least one available to each compression cell. Of course it does not matter if the spacing is less but there would not theoretically be any benefit except to provide a more adequate passage for the gas.

With regard to preventing damage in the event of a hydraulic lock, it will be seen that if the compressor starts up or in the course of operation encounters a situation where an inlet cell contains a volume of liquid, either oil, refrigerant or a mixture of both, such that as the volume of the cell reduces during rotation it would, unless otherwise protected, break one of the blades or stall the compressor, the confined liquid will escape through one or more of the discharge ports.

Gas expansion motors, such as used in a Rankin cycle, are often constructed similarly to the vane compressor described above, and they suffer from the corresponding problem of needing to cope with a variable expansion ratio. The solution is similar: locating non-return valves in the same way on the outlet side of the expander. Thus the invention should be understood to apply equally to such motors and an example is shown in Figure 3. Here, the ports extend over a somewhat larger arc so that there is one always available to the largest reducing-volume cell, but otherwise the construction is virtually the same as the compressor.

The function of the valves of this invention must not be confused with the function of the normal valves used in conventional compressors which must essentially open and close with each discharge pulse. Otherwise they serve no purpose. In the case of this invention, the action is essentially one of non-return in relation to an average pulsating pressure. As they are not required to open and close rapidly, the valves can be of robust construction, of high inertial mass and secure against damage from hydraulic shock.

A further problem with rotary vane compressors and expansion motors is the material used for the vanes. They must of course have the necessary mechanical strength, but as they are subject to very considerable centrifugal force they bear heavily against the stator, and must also be able to sustain the resultant friction without excessive wear and with reasonable stability in relation to the temperature changes generated by the friction. There are also cost and weight factors to consider, and satisfactory dissipation of heat away from the outer vane edges. However, materials which have low friction and good wear properties seldom fulfill all these other factors, and the result is an indifferent compromise.

According to another aspect of the present invention there is provided a rotary vane compressor blade comprising a main portion of a first material and a radially outermost portion of a second material better suited to sustain friction and wear than the first.

Preferably, the outer portion is in the form of an insert which fits a slot in the main portion. For light loading, or where the material has high resistance to wear, the insert may be of simple rectangular section, and thus be narrower than the main part of the blade. For heavier loading, and to spread the contact area, the insert may be of T-section with the stem of the T in the slot and the head of the T covering the outer edge of the main portion.

The insert may conveniently be carbon or carbon compositions, silicon materials of PTFE. The main body of the blade may be of aluminium or one of its alloys, close grained cast iron, carbon or reinforced resin based compositions, or thermoplastic materials such as acetal copolymer.

Examples of such blades with inserts are shown in Figure 4 of the accompanying drawings.

CLAIMS

1. A rotary vane machine having a fluid inlet and a fluid outlet wherein, on the fluid discharge side, there is a plurality of circumferentially spaced

ports, each with a spring biased non-return valve providing passages from the decreasing volume cells between the vanes to a common manifold.

2. A machine as claimed in claim 1, wherein the ports decrease in size in the direction of rotation of the rotor.

3. A machine as claimed in claim 1 or 2, wherein the non-return valves are formed by leaf springs which normally close the associated ports.

4. A machine as claimed in claim 3, wherein each leaf spring has a rigid backing member to limit its opening.

5. A machine as claimed in any preceding claim, wherein each blade comprises a main portion of a first material and a radially outermost portion of a second material better suited to sustain friction and wear than the first.

6. A machine as claimed in claim 5, wherein the radially outermost portion is received in a slot in the radially outer edge of the main portion.

7. A machine as claimed in any one of the preceding claims configured as a compressor.

8. A machine as claimed in any one of the preceding claims configured as a motor.

9. A rotary vane machine substantially hereinbefore described with reference to the accompanying drawings.

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